Transportation Synthesis Report

Nina McLawhorn
Research Administrator
Wisconsin Department of Transportation
608-266-3199
nina.mclawhorn@dot.state.wi.us

Evaluating New Sensor Technologies for Actuated Signals

Prepared for
Bureau of Highway Operations
Division of Transportation Infrastructure Development

Prepared by
CTC & Associates LLC
WisDOT RD&T Program
December 18, 2003

Transportation Synthesis Reports (TSRs) are brief summaries of currently available information on topics of interest to WisDOT technical staff in highway development, construction and operations. Online and print sources include NCHRP and other TRB programs, AASHTO, the research and practices of other state DOTs, and related academic and industry research. Internet hyperlinks in TSRs are active at the time of publication, but changes on the host server can make them obsolete. The Wisconsin Department of Transportation does not endorse or attest to the accuracy of information on externally linked pages.

Request for Report

A fully actuated traffic signal includes mechanisms installed on both the major and minor roads that detect the volume of traffic present. Based on the amount of traffic, the signal provides enough time to accommodate all of the vehicles[1]. A simple traffic-actuated signal installation has four components: the controller unit, the detectors, the traffic lights and the connecting cables. The "inductive loop" is by far the most common type of detector, consisting of a loop of wire embedded in the pavement. The metallic mass of a vehicle traveling over the detector changes the inductance of the loop: the detector processes this change and notifies the controller unit of the presence of a vehicle[2].

[1] *Traffic Signals*, Washtenaw (MI) County Road Commission: http://www.wcroads.org/POLICIES/RDCtrfcSgnl.htm.
[2] *Managing Traffic Flow Through Signal Timing*, Public Roads, January/February 2002: http://www.tfhrc.gov/pubrds/janfeb02/timing.htm.

To date, the inductive loop has been the detector of choice for WisDOT, and this method presents a number of advantages: flexible design to satisfy a large variety of applications; mature, well-understood technology; large experience base; provides basic traffic parameters; and high frequency excitation models provide classification data[3]. A number of transportation agencies including WisDOT have begun to seriously consider using other more recently developed detector technologies such as microwave radar and video image processing, which overcome a shortfall inherent in the inductive loop[4]: installation of the loop requires a pavement cut that can decrease pavement life[5].

[3] *Systems Engineering Processes for Developing Traffic Signal Systems*, NCHRP Synthesis 307, 2003; Ch. 3, p. 34- Table 10: http://gulliver.trb.org/publications/nchrp/nchrp_syn_307c3.pdf.
[4] Ibid., *Traffic Detectors*, p. 33.
[5] Ibid., Table 10.

The RD&T Section was asked to prepare a report on the newer technologies that examines their performance, costs, installation requirements, maintenance needs and other issues, and their use by other state DOTs.

Summary

We mined the Internet sites of federal transportation agencies, transportation research and safety organizations, and state transportation agencies, and explored their links to further information. We located pertinent information including description of the newer detector technologies being used in a half dozen states. To learn specifics about state DOT experience with, and evaluation of, the newer technologies, we queried eight agencies in the Midwest and other regions by e-mail.

Our research would indicate that among the states that have used the newer technologies, there is not a consensus on applicability and quality of performance. (See **State Experience**, below.) For example, the Town of Castle Rock, CO favors the installation of video detection over loop induction for a number of reasons, including the fact that wire loops can experience failure caused by deterioration and construction of new pavement. Meanwhile, the Indiana Department of Transportation has enacted a moratorium on the use of video detection due to substandard performance. The Minnesota DOT frequently uses microwave sensors and ultrasonic sensors for temporary signals where the pavement may be torn up or lanes shifted frequently etc., and reports good success with them. The Michigan DOT, meanwhile, reports that it tried microwave detection several years ago, and found it to be "not as reliable as we are willing to accept."

NCHRP Synthesis 307, *Systems Engineering Processes for Developing Traffic Signal Systems*, compares performance, purchase costs and potential applications for eight of the newer detectors in two, easy-to-read tables. (See **Performance and Cost** below for the Web links.) The technologies evaluated in the tables include: magnetometer (two-axis fluxgate magnetometer), magnetic (induction or search coil magnetometer), microwave radar, active infrared, passive infrared, ultrasonic, acoustic and video image processor. Costs (in 1999 U.S. dollars) range from $385 to $2,000 for a magnetic (induction coil) sensor, to $5,000 to $26,000 for a video image processor sensor.

Like WisDOT, the British Columbia Ministry of Transportation and Highways is investigating new detection technologies as possible replacements for magnetic loops (**Research**). The ministry is examining video image processing, ultrasonic and microwave technology with the goal of lowering the cost of vehicle detection while improving accuracy and quality of information. In other research, the Texas DOT is developing guidelines for planning, designing, installing and maintaining video detection/control systems at new and existing intersections and interchanges.

State Experience

Caltrans

Caltrans Has Eyes to See, Roads and Bridges, Vol. 38, Issue 10, October 2000.
TRIS Online abstract at:
http://199.79.179.82/sundev/detail.cfm?ANNUMBER=00800678&STARTROW=1&CFID=363198&CFTOKEN=11748195.
While many technologies can be used for traffic surveillance and accident detection, including loop detectors, infrared sensors, radar, acoustics, video cameras and video processing systems, a California vendor was able to provide customized components designed per Caltrans' specifications for its closed-circuit television system. The company also was able to integrate with these other detection technologies to provide for a real-time traffic adaptive control, surveillance and support system. The full article is available from bwilson@sgcmail.com, Scranton Gillette Communications Inc., 380 E Northwest Highway, Des Plaines, IL 60016-2282.

Town of Castle Rock, CO

Traffic Signal Information
http://www.crgov.com/page.asp?navid=265.
Castle Rock, CO uses fixed-time signals and traffic-actuated signals. Some traffic-actuated signals use video cameras to detect vehicles as they approach the intersection. The cameras are focused on the lane approach to the signal so that when a vehicle enters the image a detection command is sent to change the signal. This technology replaces the older loop technology that is used at many of the town's traffic signals. The wire loops can experience failure caused by deterioration and construction of new pavement, while the camera detection is not harmed in these situations. The cameras also allow adjustments should the lanes change as a result of construction or redesign.

Indiana DOT

Contact: James Sturdevant, Traffic Systems Engineer, INDOT Operations Support
E-mail: jsturdevant@indot.state.in.us; Phone: 317-232-5073.

"INDOT has experience with a wide variety of non-invasive detection technologies," James said. "We have found that the only detection technology as accurate and reliable as an induction loop is an induction loop. INDOT is designing an increasing quantity of paved over pre-formed loops in the base of the pavement, with loop lead-ins going directly to the handhole for the splice. This type of installation leaves the pavement surface free of saw cuts and detector housings, eliminating the most common failure points. In circumstances where induction loops cannot be used (failed pavement, certain bridge decks, brick surfaces), INDOT uses the following:

- "Magnetometers / microloops- an option where a traditional loop cannot be sawed in. They can be mounted beneath bridge decks, bored in or directional horizontal bored under lanes. Microloops used in conjunction with Canoga loop amplifiers hold presence detection and do pulse detection as well as a traditional loop. Microloops with standard (non-Canoga) loop amplifiers work well in pulse mode, but may drop calls in presence mode.
- "Video- INDOT has enacted a moratorium on the use of video detection due to substandard performance. Rain, snow, fog, wet pavement, headlight glare, sunrise/sunset, wind, lighting changes, shadows, and occlusion from adjacent and crosslanes can all cause detection errors. Use only where induction loops are not practical.
- "Microwave (Doppler)- only applicable on approaches without separate left turn phase associated with the through phase. Lane to lane differentiation difficulties. Use only where induction loops are not practical."

Lexington, KY

Traffic Q&A, Lexington Herald-Leader, posted Aug. 18, 2002.
http://www.kentucky.com/mld/kentucky/news/local/3887482.htm

Most of the city's stoplights are actuated signals. Vehicles are detected by loops -- actually metal sheets with wire sensors -- located underground near the stop bars. Some lights also have video detectors mounted above the intersection. Lexington will soon study some different traffic-monitoring technology. The study, scheduled to run through June 2003, will evaluate acoustic, microwave and video detection technologies. All three types of detectors will be placed at 10 intersections in the city. The study will evaluate the video detectors already in place alongside the other options to determine which works best.

Michigan DOT

Contact: Paula Corlett, Supervising Engineer, Traffic Signals Unit
E-mail: corlettp@michigan.gov; Phone: 517-373-2324.

"Currently we rely most often on embedded loop detectors for actuation of traffic signals," Paula said. "Within the last two years we have begun using video detection with varying results. Since Michigan uses span wire installation primarily, we are not always able to place the video camera at the best vantage point. This has led to not getting proper coverage of the approach we are trying to detect. Now, if video detection is recommended, we are reviewing the location in the field prior to doing a full design to determine if there are poles that are available or that can be placed that will provide the necessary installation point for the camera. This has improved our ability to get the proper detection.

"But by the same token," Paula said, "we are finding that the old method of embedded loops is most often the most reliable tool in providing detection for traffic signals. Several years ago, microwave detection was tried and found to be not as reliable as we are willing to accept."

Minnesota DOT

Contact: Ray Starr, Traffic Electrical Systems Engineer
E-mail: ray.starr@dot.state.mn.us; Phone: 651-284-3434.

"Mn/DOT uses loop detectors for nearly 100 percent of our permanent signals," Ray said. "For temporary signals where the pavement may be torn up or lanes shifted frequently etc., we frequently use microwave sensors (Microwave Sensors Model TC-20 or 26B) and ultrasonic sensors (Microwave Sensors Model TC-30). We can mount these on the span wire. We have had good success with them."

AUSCI (Adaptive Urban Signal Control and Integration) Evaluation Final Report, Mn/DOT, 2000
http://www.dot.state.mn.us/guidestar/pdf/ausci/finaloct00.pdf.
This report presents an evaluation of the AUSCI Intelligent Transportation System Field Operational Test in Minneapolis. The project involved a 56-intersection portion of Minneapolis, employed the SCOOT adaptive control system, and used 138 video sensors to provide the system's detection requirements. The evaluation examined the institutional and technical issues, and project costs associated with deployment. In addition, transportation system impacts of SCOOT featuring travel time runs and intersection delay studies, are examined.

Signal & Lighting Design Course Workbook, June 1999
Mn/DOT Office of Traffic Engineering
http://www.dot.state.mn.us/metro/trafficeng/dsg_crse/chap31.html.
From: Ch. 3, Detection; 3A-2, Types of Detection

- C. Certain off-the-shelf auxiliary detector logic that extends the capabilities of the normal detector/controller hardware configuration is also available. This equipment employs auxiliary timers and display monitoring circuits. This logic allows the enabling and disabling of selected detectors, control of the yield of green, and the activation of "Hold-in Phase" circuits in order to supplement the logic of the controller. An example is the "green extension system" for the purpose of providing dilemma-zone protection at a semi-actuated intersection.
- 3A-2.2: Microwave Radar Detectors.
  This type of detector has been deployed extensively in Europe. The principles of operation involve microwave energy being beamed on an area of roadway from an overhead antenna, and the vehicle's effect on the energy detected. (Note: subsequent discussion includes capabilities, disadvantages and performance characteristics.)
- 3A-2.3: Video image processing
  Vehicle detection by video cameras is one of the most promising new technologies for non-intrusive large-scale data collection and implementation of advanced traffic control and management schemes. This concept provides real-time vehicle detection and traffic parameter extraction from images generated by video cameras. Major worldwide efforts have been directed at development of a practical device for image processing. Under FHWA sponsorship, a wide-area, multi-spot Video Imaging Detector System called Autoscope was developed at the University of Minnesota and is commercially available [Video Track is also available]. (Note: subsequent discussion includes performance characteristics and advantages.)

Oregon DOT

Evaluation of Microwave Traffic Detector at the Chemawa Road/Interstate 5 Interchange
Report No. FHWA-OR-DF-02-05, April 2002
http://www.odot.state.or.us/tddresearch/reports/microwave.pdf.
In 2001, the Oregon Department of Transportation installed a microwave traffic detection sensor, and compared its performance to conventional inductive traffic loops. The objective of the study was to evaluate the capabilities of the microwave traffic detection sensor to function as a viable detection device in a signalized intersection. The sensor was to detect vehicles in advance of the intersection, providing "extension" and "call" functions for the signal controller. The microwave detector provides a non-intrusive method of detection and the need to cut grooves is eliminated. The microwave sensor can be installed and maintained from the shoulder area with lower impact on the motorist. Safety for highway workers is also improved. The Remote Traffic Microwave Sensor was installed and traffic counts made over four weeks. The microwave sensor generally counted lower than the traffic loops. Potential errors for various traffic conditions for both the inductive loops and the microwave sensor were identified and analyzed. Although the counts differ, the microwave sensor provides reasonable detection for the extension and call functions. This study did not look at long-term performance or cost benefits of the detector.

Virginia DOT

VDOT installs camera at Dayton intersection, March 2003
http://www.virginiadot.org/infoservice/news/newsrelease.asp?ID=STAN-081.
The Virginia Department of Transportation is installing a camera to control traffic signals for eastbound traffic on Route 290 at the intersection of Route 42 in the Town of Dayton. After observing the intersection the department determined that a malfunctioning wire loop under the road was not triggering the light cycles and that a single camera mounted on the west side of the intersection will be sufficient to correct the problem. It is the practice of VDOT Staunton District to use the wire loops under the road until they go bad, and then to replace them with cameras, which do not require lane closures for maintenance. The work is being performed by VDOT signal technicians. The work will cost $4,300 and will come from the Staunton District's signal maintenance fund.

Performance and Cost

Systems Engineering Processes for Developing Traffic Signal Systems, NCHRP Synthesis 307, 2003
From Ch. 3- Traffic Signal Systems Engineering:
http://gulliver.trb.org/publications/nchrp/nchrp_syn_307c3.pdf.

- p. 33- Traffic Detectors. Tradeoffs for selecting detectors are provided in some of the FHWA handbooks (Gordon et al. 1996; Carvell et al. 1997), as well as other material. FHWA and other agencies have published results comparing test data for various detectors (Klein and Kelley 1995). Klein (2001) provides a reference for detector technology, as well as the analysis and algorithms for estimating state variables. An extensive set of references on detectors and related technologies is also provided.
- p. 34- Table 10- Strengths and Weaknesses of Commercially Available Sensor Technologies. The technologies evaluated in the table include: magnetometer (two-axis fluxgate magnetometer), magnetic (induction or search coil magnetometer), microwave radar, active infrared, passive infrared, ultrasonic, acoustic and video image processor.
- p. 35- Table 11- Traffic Output Data (Typical), Communications Bandwidth, and Cost of Commercially Available Sensors. The technologies listed in Table 10 are profiled.

Research

Video Detection Guidelines for Intersections and Interchanges
TRB Research in Progress: start 2001- active.
http://rip.trb.org/browse/dproject.asp?n=7130
RiP abstract: The objective of this Texas DOT project is to develop guidelines for planning, designing, installing and maintaining video detection/control systems at new and existing intersections and interchanges. Two products are expected: an intersection video-detection manual and a field handbook. (Project contacts are provided.)

Vehicle Detector Study
TRB Research in Progress: start 1998- active.
http://rip.trb.org/browse/dproject.asp?n=4247
RIP abstract: The British Columbia Ministry of Transportation and Highways uses vehicle detection for many purposes, and currently uses magnetic loops for vehicle detection. New detection technologies provide more accurate and reliable information at a lower cost. New detection technologies should be investigated for use as a replacement for magnetic loops. The research objective of this project is to research alternative detection technologies such as video image processing, ultrasonic and microwave technology. The objective is to lower the cost of vehicle detection while improving accuracy and the quality of information. The research deliverables are to: perform a field study; prepare a report comparing the different technologies on the market today; and recommend the preferred detection technology for intersection and freeway applications.